UNITED STATES DEPARTMENT OF AGRICULTURE
Bureau of Agricultural Engineering
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BRIEF INSTRUCTIONS FOR
THE DESIGN AND CONSTRUCTION OF SMALL DAMS
FOR EMERGENCY CONSERVATION WORK IN NORTH DAKOTA

by

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SCOPE OF INSTRUCTIONS

These instructions cover the design and construction of dams suitable for Civilian Conservation Corps work in North Dakota. Any deviation from these instructions by C.C.C. employees must be approved by the Supervising Engineer assigned to the Regional Forester's Office, Milwaukee, or by proper state officials designated by the Regional Forester. If sufficient rock is not available within reasonable distance to construct the dams as shown in the plans, or other features of design would necessitate an unusually high cost, the circumstances should be reported to the proper officials with recommendations.

Dams to be constructed under the Emergency Conservation Works water conservation program of North Dakota shall be limited to the following average heights above stream beds: earth dams, 20 feet; rubble masonry dams, 10 feet; timber crib dams, 8 feet.

The dams to be built are intended primarily to store water for flood control and water conservation purposes and to raise the water table in bottom lands. No provision has been made for drainage of the reservoir. If a sluiceway is required to empty the reservoir, a special design for the structure should be prepared.

The designs and specifications contained in this report should be used cautiously for work in other states. The public character of the Civilian Conservation Corps work, the large number of structures planned, the limited number of engineers experienced in dam construction to supervise the work, and the necessity of using more hand labor and buying less material, where this is possible, have made it desirable to design conservatively. Where small dams are constructed under experienced engineering supervision and under favorable soil conditions, it may be possible to effect some saving by simplifying certain of the specifications. However, such changes should be made with extreme caution. Each dam usually merits a separate study and individual design by a competent engineer.

Some states have strict legel requirements for the construction of dams. These requirements should be carefully investigated by a person contemplating the building of a dam.

IMPORTANCE OF ENGINEERING SUPERVISION

The design and construction of all dams require the exercise of care and mature judgment in order to obtain both safety and economy. The failure of a small dam may cause considerable damage or even loss of life. Every precaution must be taken by Civilian Conservation Corps workers to construct dams that have an adequate factor of safety. No dam shall be built where loss of life is likely to occur if the structure should fail.

Due consideration must be given to economy of construction in recommending projects. Only projects having a reasonable estimated cost per acre foot of storage will be approved for construction. No project should be approved for construction if the estimated cost exceeds $150 per acre foot. This figure should serve only as a maximum guide for important projects. It is imperative to keep the cost per acre foot as low as is consistent with safe practice.

GENERAL INSTRUCTIONS AND FIELD DATA TO BE SECURED

A topographic survey should be made of the dam and reservoir site and all spillway locations, and the following information should be obtained for design and estimating purposes.

1. Sufficient topographic information should be obtained from maps or surveys to estimate acre feet of storage and watershed area.

2. A profile along the center line of the proposed dam should be secured. The profile should be extended across banks of stream to an elevation at least 3 feet above maximum height of dam or a linear distance of 200 feet from the spillway location. Similar profiles at right-angles to the stream should be made at critical points upstream and downstream from the proposed dam.

3. High water marks in the channel should be determined and elevations noted on profile. Discharge measurements should be made by use of a float if the stream is flowing.

4. Borings should be made or test pits should be dug at 10 to 25 foot intervals along center line of dam to determine the foundation conditions. In no case shall there be less than five borings taken at any proposed site to a depth equal to 1/2 to 3/4 the height of the proposed dam.

5. The surface and subsurface soils of the proposed foundation of the dam, vegetative conditions, location of old channels, and geologic conditions that might affect the design of the structure, should be determined and accurately described.

6. Locations of construction materials, especially clay, sand, gravel, and rock, should be determined and quantities available and distance from site noted.

7. Investigation should be made to determine whether crawfish, muskrats, or other burrowing animals will probably be active.

8. Data should be secured showing value and importance of project and factors affecting design, such as land ties, names of property owners adjacent to site, location of roads, low water fords upstream, sewer outlets, and location of nearby farm buildings, houses or other improvements which might be affected by the proposed dam.

9. Complete information should be secured from interested parties as to the amount and extent of cooperation. Preference should be given to those projects on which farmers will cooperate by furnishing teams, native construction materials, a small acreage adjacent to the reservoir for the use of the public, a right-of-way to the dam site, and will fence the dam.

10. In western North Dakota a tributary area of at least five square miles is desirable for each acre-foot of reservoir capacity to secure a stable water level. In eastern North Dakota three sections of tributary area per acre-foot would provide a reasonably stable water surface. A spring-fed reservoir is desirable and if it can be obtained will permit a modification of this rule. This rule may also be modified where a stable water surface is not essential.

DESIGN OF EARTH DAMS

Only earth dams having an average height of 20 feet or less above
the stream bed are approved for construction by Emergency Conservation
Corps camps in North Dakota. The design and construction of higher dams
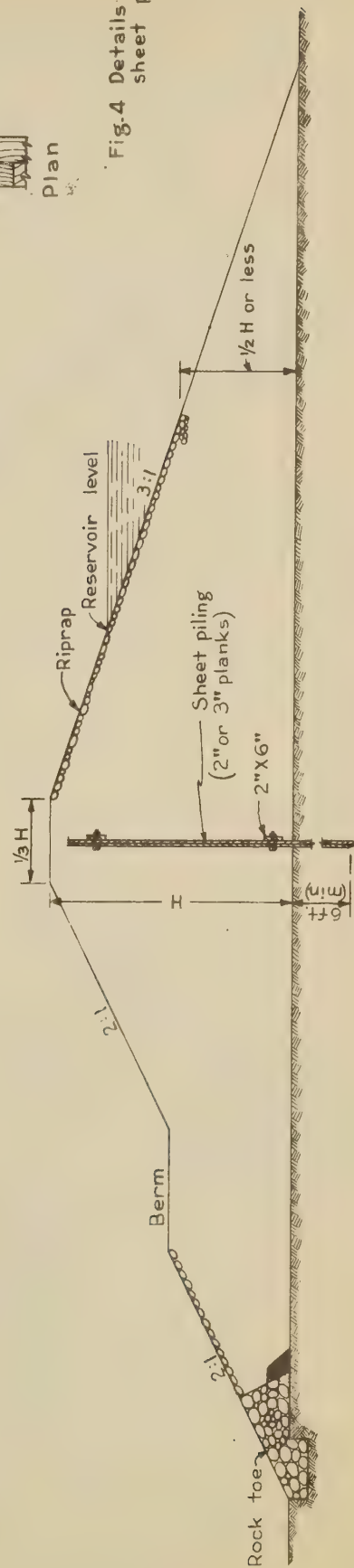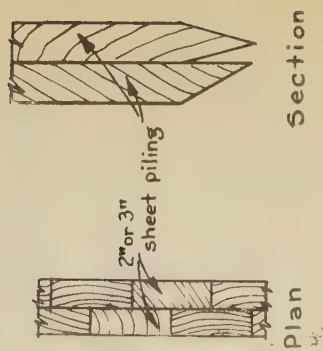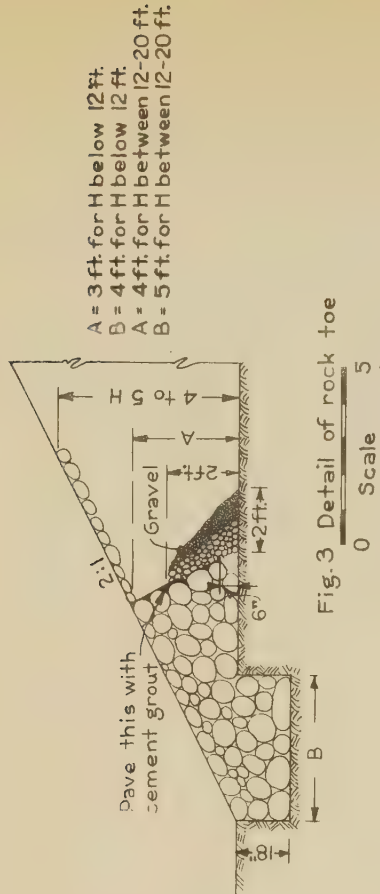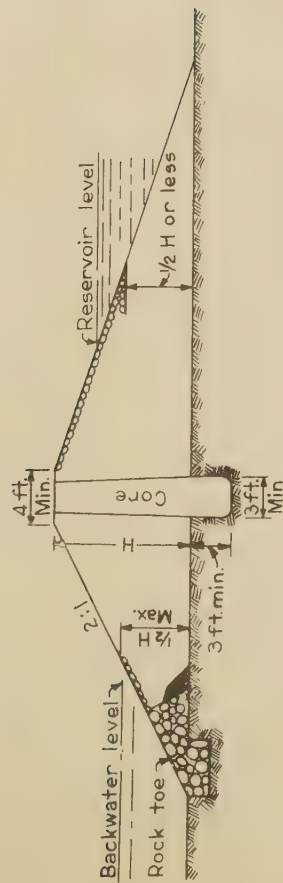are not considered in these instructions.

An allowance of approximately 10 and even 15 per cent for some
structures, must be made for the settlement of earth dams; for instance,
a dam 20 feet high should be constructed at least 22 feet high. The
heights referred to in this report relate to the finished cross-section
after settlement.

The section which should be used for dams below 12 feet in height
is shown in Figure 1 and the section to be used for a dam 12 to 20 feet
high is shown in Figure 2. Details of construction are shown in Figures
3 to 6. The top width of a dam should be approximately one-third of the
height unless the top of the dam is to be used as a roadway requiring a
top width of 8 to 12 feet. A minimum top width of 4 feet should be used.
The upstream slope shall be not less than 3 horizontal to 1 vertical, and
the downstream slope shall be not less than 2 horizontal to 1 vertical.

As a general practice for C.C.C. work, a berm should be placed on
the downstream slope of all dams exceeding 12 feet in height where the
top width does not exceed approximately one-third the height. The height
of the berm should be made 6 to 8 feet above the bed of the stream and its
width should vary from 8 to 12 feet.

The top of the berm should have a slight slope downstream. The
downstream slope of the dam should be protected with a rock toe and rip-
rapped, as shown in Figures 1 and 2.

Collecting drains are used to drain the downstream part of many
dams to dry out wet foundations and prevent saturation of the downstream
toe. Projects requiring the use of collecting drains to insure the
safety of the structure shall be submitted to the supervising engineer
attached to the U. S. Regional Forester's Office for approval.

A = 3 ft. for H below 12 ft.
B = 4 ft. for H below 12 ft.
A = 4 ft. for H between 12-20 ft.
B = 5 ft. for H between 12-20 ft.

Pave this with cement grout

Gravel

2 ft.

6"

2 ft.

2:1

A

4 to 5 H

B

.18"

Fig.3 Detail of rock toe

0   Scale   5

Section

2" or 3" sheet piling

Plan

Fig.4 Details of timber sheet piling.

Reservoir level

½ H or less

3:1

Riprap

⅓ H

Sheet piling (2" or 3" planks)

2" x 6"

H

2:1

Berm

Rock toe

6 ft. (min.)

½ H or less

Fig.2 Cross section of earth dams 12 to 20 feet high.

Backwater level

Reservoir level

Rock toe

4 ft. Min.

H

Core

3 ft. Min.

3 ft. min.

½ H Max.

2:1

½ H or less

Fig.1 Cross section of earth dams 12 feet high or less

Fig. 6 Plan of earth fill with natural spillway.

A = Details to be determined in the field.

Fig 5 Plan of excavated spillway and earth dam: Maximum height 20 feet.

PROTECTION FOR EARTH DAMS

If the reservoir covers more than approximately one acre of ground the earth dam shall be protected against wave action. For emergency conservation work in North Dakota the upstream protection shall be confined to rock riprap unless permission is secured through regular channels to use other means of protection. Riprap shall be placed on the upstream and downstream faces of the dam, as shown in Figures 1 and 2. If no large stones are available and there is an adequate supply of coarse gravel, good protection can be obtained by placing a 12 to 24-inch layer of this material on the slopes of the dam.

The type of protection necessary for the downstream face and toe of the dam depends upon the foundation, height of dam, and height and duration of backwater. A triangular ridge of rock having a height of 3 or 4 feet (see Figure 3) should be constructed. This rock protects the downstream toe from sloughing off. This protection is especially desirable where the stream will be diverted through the spillway into the channel below the dam and cause backwater eddies against the downstream toe of the dam. By paving the inside face of the rock toe, as shown in Figure 3, dirt from the dam will be prevented from washing down the slope and filling the rock voids. An opening of at least 6 inches next to the ground should be left without grouting in order to permit the seepage water to drain freely. The rock toe should be backfilled with gravel and sand to act as a filter, as shown in Figure 3, thus preventing any large amount of earth from washing through the toe.

Riprap should be laid on the downstream slope at least to the elevation which will be reached by normal spring flow. It is estimated that by placing riprap to an elevation of .4 H to .5 H an ample factor of safety is secured. Protection of the top of the berm with riprap may be required if, in the opinion of the supervising engineer, it is necessary. When designing the spillway, an attempt should be made to deflect the currents away from the downstream face of the dam to minimize the effect of eddies. (see Figure 5). The drainage of surface water from the slopes of the dam and from adjacent banks should also be planned so as to prevent erosion. Where considerable surface water is concentrated after rains, it is advisable to pave natural channels with rock. The top and downstream slope should be either sodded or seeded.

The dam must be fenced in by the cooperator. Live-stock roaming over the dam will cause much damage to the structure. It is the superintendent's job to see that the cooperator encloses the dam with a fence.

CORE WALL AND SHEET PILING

Sheet piling may be required by the supervising engineer for earth dams less than 12 feet in height for protection against burrowing animals. For dams below this height, where sheet piling is not required, a tamped clay core shall be constructed. To construct this clay core an impervious clay shall be selected, placed in position in thin layers, sprinkled with water, and carefully tamped in place by hand. (See Figure 1).

For earth dams 12 to 20 feet high, wood sheet piling shall ordinarily be used where the dam is endangered by burrowing animals. A double row of sheet piling extending up to the elevation of high water should be driven. Planks 2 inches thick should be used if they can be driven; otherwise 3-inch planks should be used. The planks should be staggered and securely bolted together. (See Figures 2 and 4). If the foundation contains so many rocks and boulders that the sheet piling cannot be driven, it will be necessary to excavate a deep trench in which to set the piling, or some other type of core wall must be used.

If, in the opinion of the supervising engineer, another type of core wall is better suited for a structure, a rubble masonry, concrete, or clay puddle core, or steel sheet piling may be used. If properly constructed, these types reduce seepage satisfactorily, are structurally safe, and all except the puddled clay type are effective against burrowing animals. The choice of type of core wall depends on its cost and on the location of the dam, the materials available, the cost and importance of the project, and the damage that would result in case of failure.

The effectiveness of the masonry type of core wall against burrowing animals as compared with the puddled clay type is a very important advantage if the dam will have only occasional inspection. A crack in the masonry wall is not attended by so much danger as a breach or puncture in a clay puddle core. The masonry wall is better adapted than the clay puddle to making connections with outlet conduits, rock or masonry abutments, or rock foundations. The puddled clay core is more flexible and is less likely to be ruptured by the unbalanced pressure in the dam than the more rigid masonry wall. A masonry core wall requires firm rock for the foundation or else the footings must rest on solid earth. Puddle construction requires the exercise of good judgment in the selection of materials and skill in their mixing and placing.

Puddled cores can often be used to advantage in low extensions of the dam on the banks of a stream. In projects where there is a knoll between the dam and the spillway, borings or pits should be used to determine whether sand or gravel strata exist which might weaken the structure. Where such strata exist, clay puddle cores or sheet piling should be used to break natural lines of seepage.

FOUNDATION AND CONSTRUCTION

The most suitable material on which to place an earth dam is clay containing a small amount of silt or sand. In preparing the foundation the greatest precautions should be taken to insure a safe structure. All sod, brush, trees, roots, and other perishable matter shall be removed from the entire area to be occupied by the dam and such material shall not be used in the dam. Soft, mucky soil should be removed from the foundation. The entire surface should be plowed or scarified to insure a firm bond between the dam and the foundation.

If sheet piling is to be used, it may be driven along the center line of the dam without constructing a trench. It should be driven to a depth of at least half the height of the dam, or should be driven through any pervious strata of gravel or sand. If deep strata of sand and gravel are encountered the site should be abandoned and a new site located. When a core of puddled earth is used instead of sheet piling, a trench should be excavated having a minimum depth of 3 feet and a minimum width of 3 feet. This trench should be deep enough to cut off any strata of gravel and sand found beneath the site and should extend a minimum of 2 feet into impervious strata.

The core trench should be backfilled with clay and it is permissible to have a slight amount of sand mixed with the clay. If an abundant water supply is available, the clay core shall be puddled and should extend to the top of the dam. If water is scarce, the material selected for the clay core must be sprinkled and tamped firmly in place.

The stream banks which will be covered by the dam should be sloped and then scarified. The amount of slope depends on the soil. This sloping will reduce the tendency to form shrinkage cracks along well defined planes and produce more equal settlement.

The dam should be constructed to the dimensions shown in Figures 1 and 2 from carefully selected materials. Slope stakes should be set for the proper width of fill. Inpervious sandy or gravelly clay which is firm when wet is considered the best material for dam construction. If there is not sufficient material to construct the whole of the dam of watertight material, that which is most watertight should be placed in the upstream and center sections of the dam. The coarser materials should be placed in the downstream section of the dam.

The fills should be constructed in layers not over 12 inches thick. The layers should be placed to the full width at all levels. At the completion of each week's work a slight ridge should be constructed around the edge of the fill in order to collect any rain that may fall and help to settle the earth.

The travel of teams and wagons or scrapers over the embankment should be distributed to secure as thorough and uniform compacting as practicable. If this does not produce a firm, well compacted embankment at all points the fill should be sprinkled with water if possible and rolled with a horse drawn roller. A good roller can be constructed from a 50-gallon oil drum filled with concrete with a 2-inch pipe through the center. Such rollers have been satisfactory in construction work.

The rock protection for the downstream toe should be carefully constructed, as shown in Figure 3. Large boulders and rocks encountered during construction should be placed in the downstream toe.

All earth fills should be completed approximately one month before freezing weather is likely to occur. In order to insure safety, it is imperative that the earth fill be permitted to settle for at least this long a time before freezing takes place in the fall.

SPILLWAY DESIGN

The importance of designing an adequate spillway cannot be overstated because more dams fail due to inadequate spillway capacity than from any other single cause. The probable maximum run-off from the watershed area tributary to the dam should be carefully estimated and an adequate spillway provided, taking into consideration the importance of the project and the damage which would result in case the dam were overtopped.

The maximum flood discharges recorded from small watershed areas have varied from less than 10 cubic feet per second per square mile to more than 2,000 cubic feet per second per square mile. The highest rates of run-off are likely to occur only after very intense precipitation when the ground is either frozen, covered with snow, or saturated from previous rains. Frequently it is not feasible to design a spillway for the maximum possible flood. To do so might involve such a large and expensive spillway that the project would not be practicable. Therefore the problem usually consists of selecting the run-off coefficient justifiable for the project.

DETERMINATION OF SPILLWAY CAPACITY

For convenience in determining spillway capacity for different projects, the probable run-off for various conditions has been estimated and recommended capacities are shown in Figure 7. These curves are determined for various watershed areas by the Rational method of computing run-off and from stream flow records. The following instructions shall govern the determination of spillway capacity of dams to be constructed by the Civilian Conservation Corps camps in North Dakota.

Curve A shall be used to determine spillway capacities of earth dams in hilly and rolling country. The flow from this type of watershed is more rapid than from flat areas and is classified as fast run-off. Earth dams must not be overtopped and an ample factor of safety must be allowed in order to insure safe structures.

Curve B shall be used for flatter slopes where slower flows will occur and represents medium run-off. This curve shall be used for earth and masonry dams where little damage will result from failure.

Curve C shall be used to determine the spillway capacity of rubble masonry and timber crib overflow dams on flat streams which will have comparatively small run-off per square mile. The rate of run-off from such areas has not been great and if the dam is overtopped slightly more than anticipated no great amount of damage is likely to occur. Curve C shall not be used to determine the spillway capacities of earth dams.

The extent of the probable damage, should the dam be overtopped, is one of the most important considerations in determining spillway capacity. The amount of water to be stored in many reservoirs contemplated for North Dakota conservation work is so small that should a failure occur at the maximum flood flow the liberation of impounded water would not greatly affect the discharge for any considerable distance down the stream valley. None of the proposed projects are located where a failure would affect villages or towns, or highly developed areas.

Projects should not be constructed where there is possibility of loss of life in case of failure.
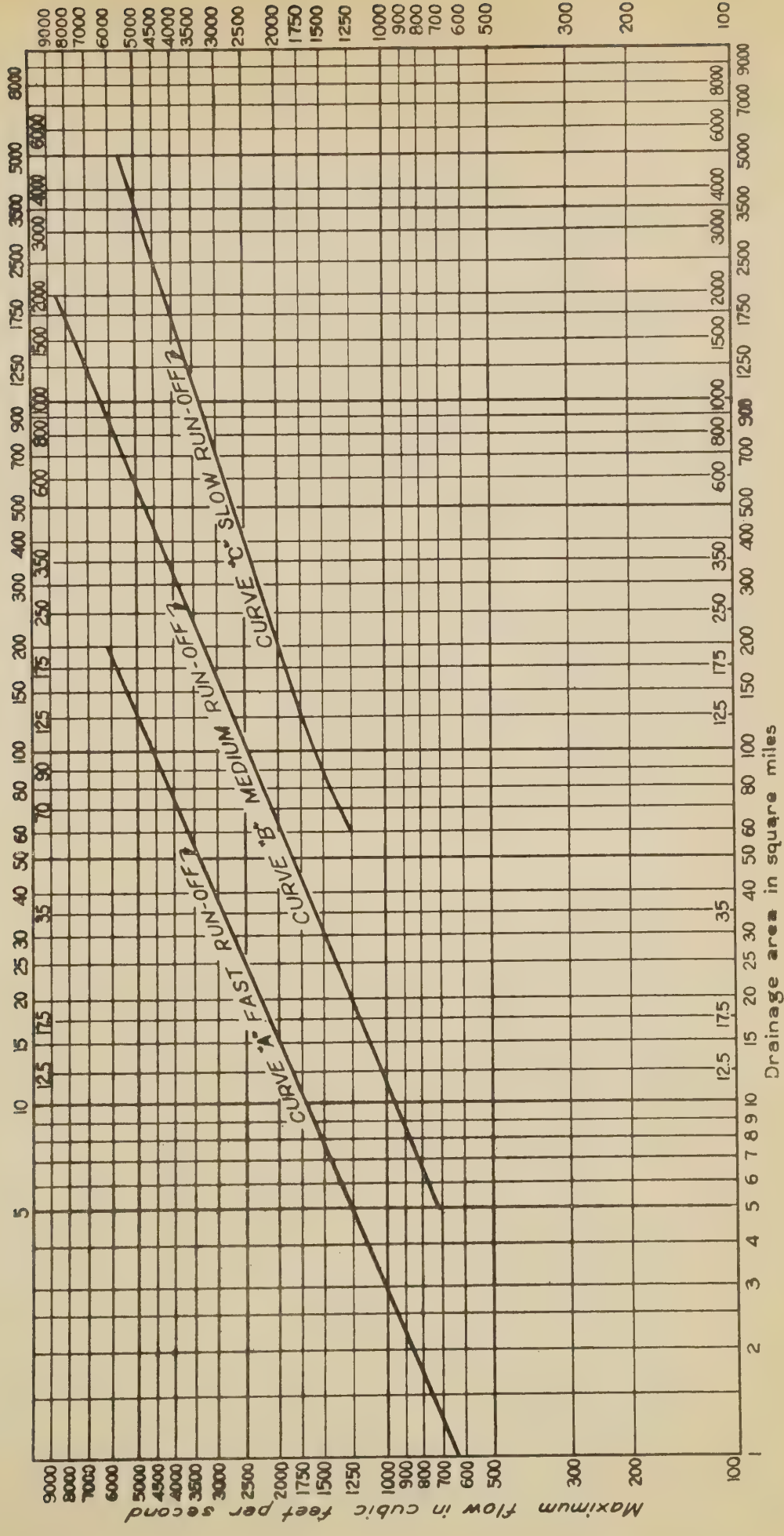
Fig. 7 Spillway capacities for small dams. North Dakota.

The flow over an excavated spillway where the entrance is sloped and there is free flow at the outlet, can be determined by the weir formula

$$Q = CLH^{3/2}$$

where Q = discharge in cubic feet per second
C = constant
L = width of spillway in feet and
H = depth of water over crest of spillway

For a paved spillway having free flow at the outlet, use C = 2.5 and for excavated spillway with loose rock riprap and free flow, use C = 2.25. Where the backwater may cause congested flow at the outlet of an excavated spillway, use C = 2.0. These figures are considered conservative.

The capacity of a natural earth spillway may be computed from Kutter's formula. The value of n for a spillway in pasture should be taken as .060. For brush or timbered spillways, the value of n should be .140. In most instances the flow across a natural spillway will have a comparatively small velocity. Ordinarily it is considered satisfactory to estimate the velocity of flow as 1 foot per second in determining the spillway capacity of flat natural spillways. However, where it is important to secure a more accurate determination, the velocity should be estimated using Kutter's formula with the values of n as stated above.

FREEBOARD

The freeboard of the dam should usually be at least 3 feet above the maximum stage estimated to occur when the spillway is discharging at the flood rate selected for the design. If the capacity of the spillway cannot be estimated accurately or is indeterminate, a larger freeboard should be allowed, depending on the damage that would result if the dam failed. If a long natural spillway is available it is permissible to reduce the freeboard to 2 feet.

CONSTRUCTION OF SPILLWAY

A natural depression can cometimes be used as a spillway. If the spillway is not paved or riprapped, the influence of vegetation on the discharge should be carefully considered.

An excavated spillway is desirable because the capacity can be determined more accurately. The spillway entrance should be flared to improve the hydraulics of the channel, as shown in Figure 5. For the same reason the bottom of the channel should be graded accurately and the sides sloped carefully. The walls and bottoms of spillways having a slope exceeding 10 per cent should be paved with rubble masonry. Floors should be hand laid and the voids filled with cement grout if desirable. The walls should be laid up as rubble masonry and pointed. If the slope is from 5 to 10 per cent the floor and walls should be riprapped. Paving is desirable even for these slopes if, in the judgment of the engineer, the soil is inclined to erode. For smaller slopes no protection is necessary except possibly a small paved or riprapped channel sufficient to carry low water flow. The outlet of the spillway should be carefully aligned so that the stream flow will be deflected in the direction of the original stream bed in order to minimize the effect of eddies which might cause erosion of the downstream face of the dam.

RUBBLE MASONRY DAMS
FIELD DATA TO BE SECURED

Data relating to foundation, topography of site, flood flow, watershed area, construction materials, and cooperation as required for earth dams (see page 2) must be secured for proposed masonry dams. Obtain sufficient information to permit of comparison of cost of earth dams, rubble masonry dams, and timber crib dams, in order that the most economical type of dam may be determined by the office force and approved by the supervising engineer.

DESIGN OF MASONRY OVERFLOW DAMS

Masonry overflow dams having an average height of 10 feet or less measured from the bed of the stream to the spillway lip are approved for construction by Civilian Conservation Corps camps and will be considered in this report. Higher dams are not planned because of difficulties encountered in constructing a masonry dam on earth foundation.

Although it is desirable to construct a masonry overflow dam on solid rock, this type of foundation will probably not be found in North Dakota projects. In designing a masonry dam for construction on an earth or poor rock foundation, the uplift pressure must be considered. Buoyancy from tail water also enters into the design and must be considered.

The types of masonry overflow dams recommended for use in North Dakota are shown in Figures 8 and 9 and other details of construction are shown in Figures 10 and 11. The principal difference in the two designs is in the method of draining the downstream apron. The apron of the section shown in Figure 8 is drained at the downstream toe and must be heavy enough to resist uplift pressure. The apron thickness T for various heights of dams is shown in Figure 8. This type of dam (Figure 8) should be used for earth foundations where topography, soil and stream flow are such that it is not likely the soil beneath the downstream apron can be drained during the winter months.

The section shown in Figure 9 should be used for locations where it is probable that the stream bed will drain during the winter months. Drains laid as shown in Figures 9 to 11 should be provided beneath the downstream apron to dry out the foundation during the winter and thus prevent the apron heaving from frost action. The water from the tile lines drains into the riprap below the downstream apron. A trench should be extended downstream for a sufficient distance to drain the riprap during the winter months. It is very important to secure a free outlet during the winter so that the apron will drain and will not be in danger of heaving from frost action.

The design of the spillway, wing wall, and sheet piling is practically the same for both sections shown in Figures 8 and 9. The lip of the spillway has been sloped in front and designed with a large section to resist ice pressure. The spillway should be slightly curved at the crest and at the base to conform approximately with the natural curve of the water. It is not considered practicable, due to construction difficulties, to round the spillway to conform to the shape of the nappe.

Unless the spillway conforms to the shape of the nappe, water may jump clear of the downstream face, causing a partial vacuum and adding to the overturning forces acting on the dam. Vent pipes should be built into the wing walls, as shown in Figures 8 and 9, to minimize the effect of such forces. The vents should be of terra cotta sewer pipe or black iron pipe; this to be determined by the supervising engineer.

The arrangement of the wing walls and apron walls depends on the topography of the stream bed and the length of the weir. These walls should have ample dimensions and should be carefully constructed so that water cannot seep around the ends of the dam. Such connections with stream banks are frequently inadequate and washing occurs around the ends. Wing walls should be so designed that the length of the path of percolation along any line beneath or around the wing walls is not less than the path beneath the dam.

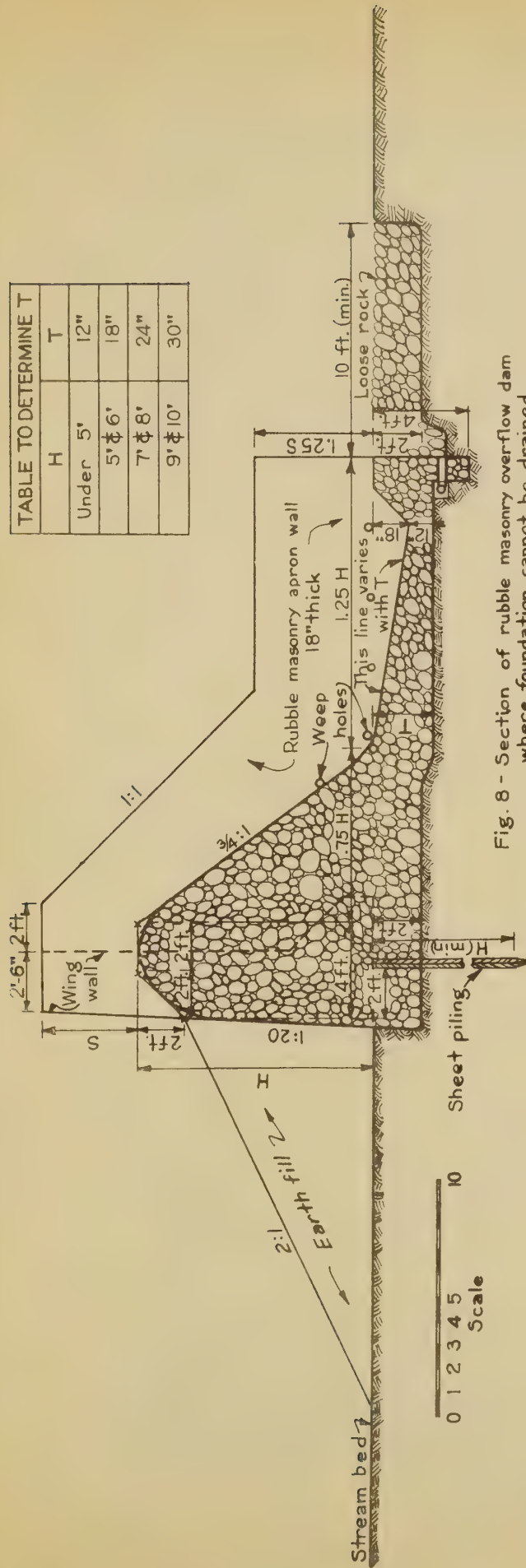| TABLE TO DETERMINE T	
H	T
Under 5'	12"
5' & 6'	18"
7' & 8'	24"
9' & 10'	30"

Fig. 8 - Section of rubble masonry overflow dam where foundation cannot be drained.
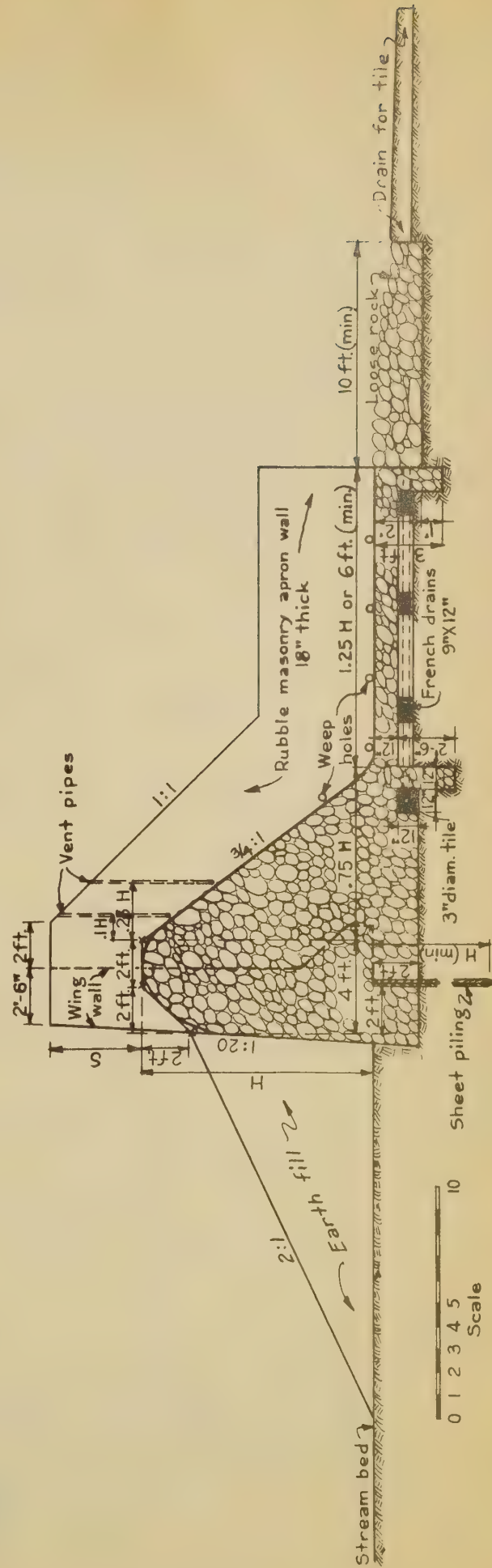
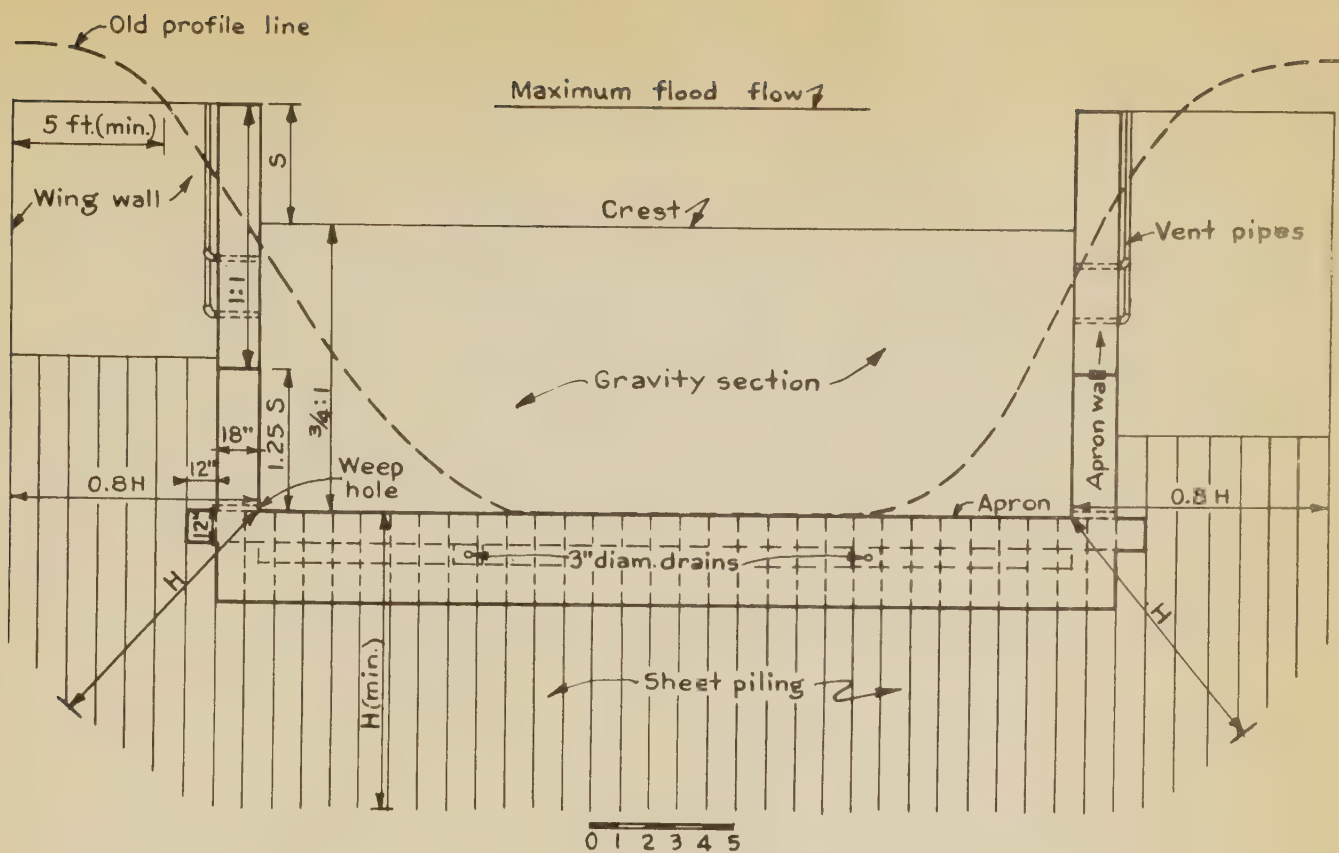Fig. 9 - Section of rubble masonry overflow dam where foundation can be drained.

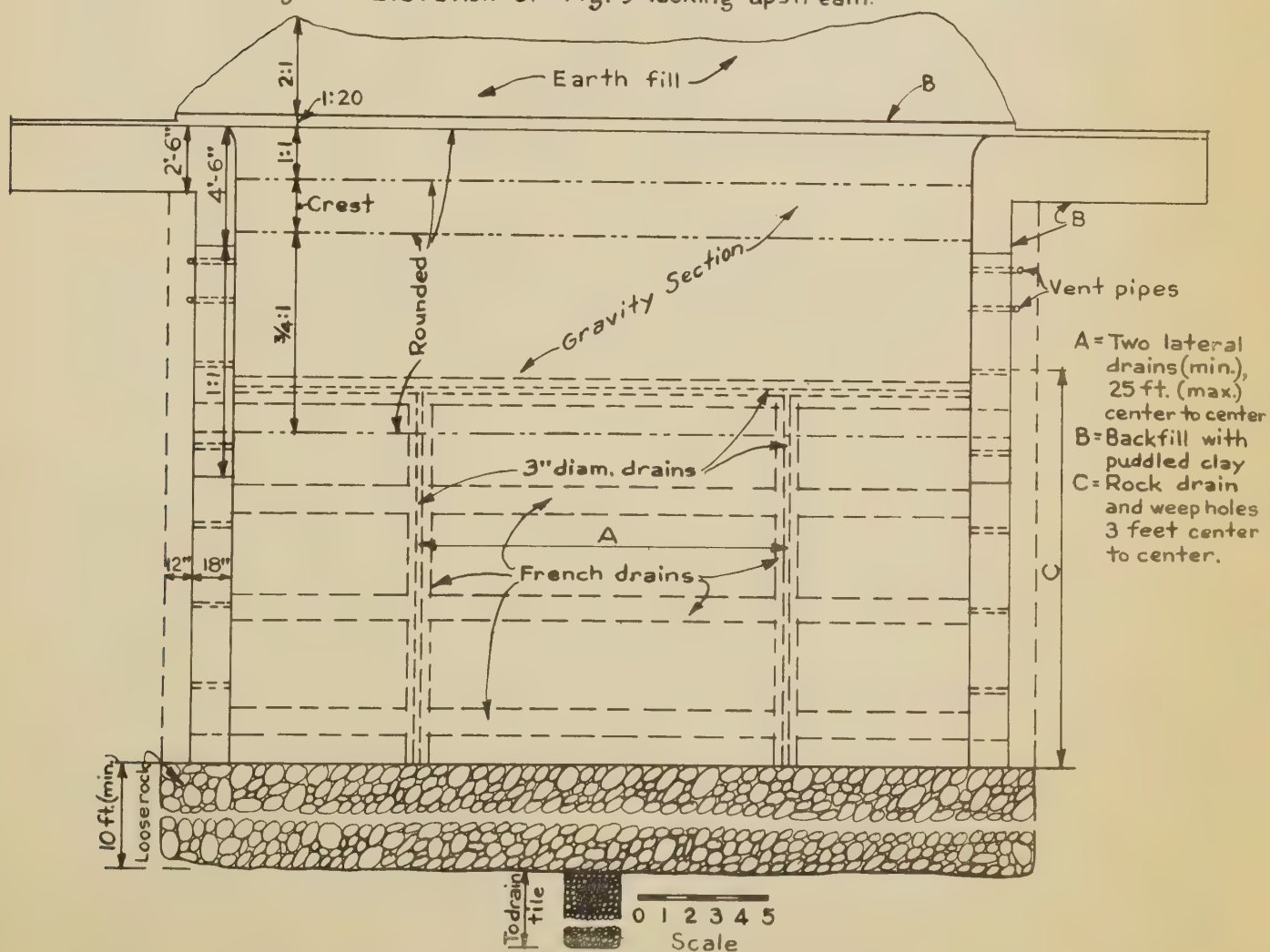Fig. 10 - Elevation of Fig. 9 looking upstream.

Fig. 11 - Plan of Fig. 9 rubble masonry overflow dam.

The apron walls should have a minimum thickness of 18 inches. An apron wall 18 inches thick will ordinarily be adequate in North Dakota and only in exceptional cases will a thicker wall be necessary. The wing walls should have a minimum thickness of 30 inches and footings, as shown in Figures 8 and 9. The height of the apron wall above the downstream apron should be at least 1-1/4 times the height of the wing wall above the spillway lip. The apron wing wall should be backfilled with porous material and drained, as shown in Figures 8 to 11. The downstream end of the backfill should be riprapped with large rocks.

Expansion joints are not considered necessary and need not be used in the rubble masonry dams covered by these instructions, even though they are necessary for concrete dams.

SIZE OF SPILLWAY

The necessary capacity of the spillway of masonry dams shall be determined from Figure 7. The discharges for spillways of different sizes and different depths of flow are shown in Table 1. This table has been computed for flow over a weir having a crest width of 2-1/2 feet, using conservative values. The wing walls and apron walls should be high enough to confine the maximum flow within the banks of the stream. A freeboard of at least 18 inches should be allowed between the elevation of the top of the wing walls and the maximum estimated reservoir stage.

The damage to the structure if the stream should overflow its banks or exceed the estimated flood stage, should be considered. Protection of the dam against such contingencies by the use of riprap at strategic points is frequently desirable.

TABLE NO. I

DISCHARGE IN CUBIC FEET PER SECOND
RUBBLE MASONRY DAMS /1

Depth above weir Feet	Length of weir notches in feet														
	1	2	3	4	5	10	20	30	40	50	75	100	125	150	200
1.0	3.0	6.0	9.0	12.0	15.0	30.0	60.0	90.0	120.	150.	225.	300.	375.	450.	600.
1.5	5.5	11.0	16.5	22.0	27.5	55.	110.	165.	220.	275.	413.	551.	688.	826.	1102.
2.0	8.5	17.0	25.5	34.0	42.5	85.	170.	255.	340.	425.	637.	849.	1062.	1274.	1698.
2.5	11.9	23.7	35.6	47.4	59.3	119.	237.	356.	474.	593.	889.	1186.	1482.	1779.	2372.
3.0	15.6	31.2	46.8	62.4	78.0	156.	312.	468.	624.	780.	1170.	1559.	1950.	2340.	3118.
3.5	19.6	39.3	58.3	78.5	98.2	196.	393.	583.	785.	982.	1472.	1964.	2455.	2946.	3928.
4.0	24.0	48.0	72.0	96.0	120.	240.	480.	720.	960.	1200.	1800.	2400.	3000.	3600.	4800.
5.0	33.5	67.0	100.5	134.	168.	335.	670.	1005.	1340.	1675.	2512.	3350.	4188.	5025.	6700.

/1   Computed from Formula $Q = 3.0 \ LH^{3/2}$

Q = discharge in cubic feet per second
L = length of weir notch in feet
H = depth of water above crest of weir.

PREPARATION OF FOUNDATION AND CONSTRUCTION OF DAM

The stream bed should be excavated to grade and to a depth of at least 2 feet below the natural stream bed. A good foundation soil is required to support a 10-foot rubble masonry dam without appreciable settlement. A solid clay or a sandy or gravelly clay soil usually makes a satisfactory foundation to resist the pressures beneath a masonry dam of the maximum height contemplated.

Drains should be carefully constructed, as shown in the plans. A trench about 9 inches square should be excavated to grade. The trench should be filled with about 3 or 4 inches of gravel graded from 1/2 to 2 inches in size. Sewer pipe 3 inches in diameter laid with loose joints should be carefully placed to grade on the top of the layer of gravel in the center of the trench and the trench filled with gravel.

If possible, wood sheet piling should be driven to a depth at least equal to the height of the dam. A foundation having porous strata should be handled in the same manner as described for earth dams by using core trenches filled with impervious material. If the sand and gravel strata are too deep, the site should be abandoned. Where it is impracticable to drive sheet piling, a rubble masonry core wall about 18 inches thick should be constructed to a minimum depth of 4 feet for smaller dams to 6 feet for a 10-foot dam.

The mortar should consist of a 1:4 mixture using Portland cement and a good grade of sand. For pointing, flush joints are considered most desirable. Where large stones are used cement can be saved by inserting spalls and small rocks into the large spaces. All rock should have clean surfaces. Cleaning should be done with wire brushes. Care should be taken to completely embed all rock in mortar. The curves shown in the plans should be obtained by placing rubble masonry along the curved planes shown. Although the rounding could be done by plastering, a thin layer of mortar would probably crack and such construction is not approved.

TIMBER CRIB DAMS
FIELD DATA TO BE SECURED

Surveys for timber crib dams require the same procedure as for rubble masonry dams. Sufficient field data should be secured to permit of the preparation of an accurate bill of materials. The materials must be available on the site before construction can be carried on economically.

DESIGN OF TIMBER CRIB DAMS

Timber crib dams shall be used where the drainage area is large, where an overflow dam is necessary, and where it is difficult to obtain rock economically for a rubble masonry structure. Crib dams are desirable where it is difficult to drain off the foundation for proper rubble masonry construction. They may be built up to a maximum height of 8 feet. The necessary spillway capacity of timber crib dams shall be determined from Figure 7. The discharges over timber crib dams for different lengths and various depths of flow are shown in Table No. 2.

The type of dam which should be used is shown in Figures 12 and 13. The abutments must be keyed into the banks so there is no chance of washing around ends. The sheet piling must be driven to a depth at least H below the profile. Two rows of sheet piling should be driven. The proper method of pointing the piling is shown in Figure 4. Planks 2 inches thick may be used if they can be driven; otherwise 3 inch planks shall be used. The two rows shall be staggered, thus forming a better seal against possible seepage. The piling shall be securely fastened to the crib and the joints protected by plates as shown. Lag screws are very efficient in fastening the piling and decking to the cribs.

The piling at the downstream end of the apron need only be of one thickness but this should reach a minimum depth of 2-1/2 feet to insure the dam against undermining. A space of 1 inch should be allowed between the downstream piling so that any water accumulating in the crib may be allowed to drain off when the backwater lowers.

Cribs, abutments, and apron must always be filled with either gravel or rock. The rock should be small enough to fill the spaces between the timbers.

TABLE NO. 2

DISCHARGE IN CUBIC FEET PER SECOND
TIMBER CRIB DAMS /1

Length of weir notch in feet

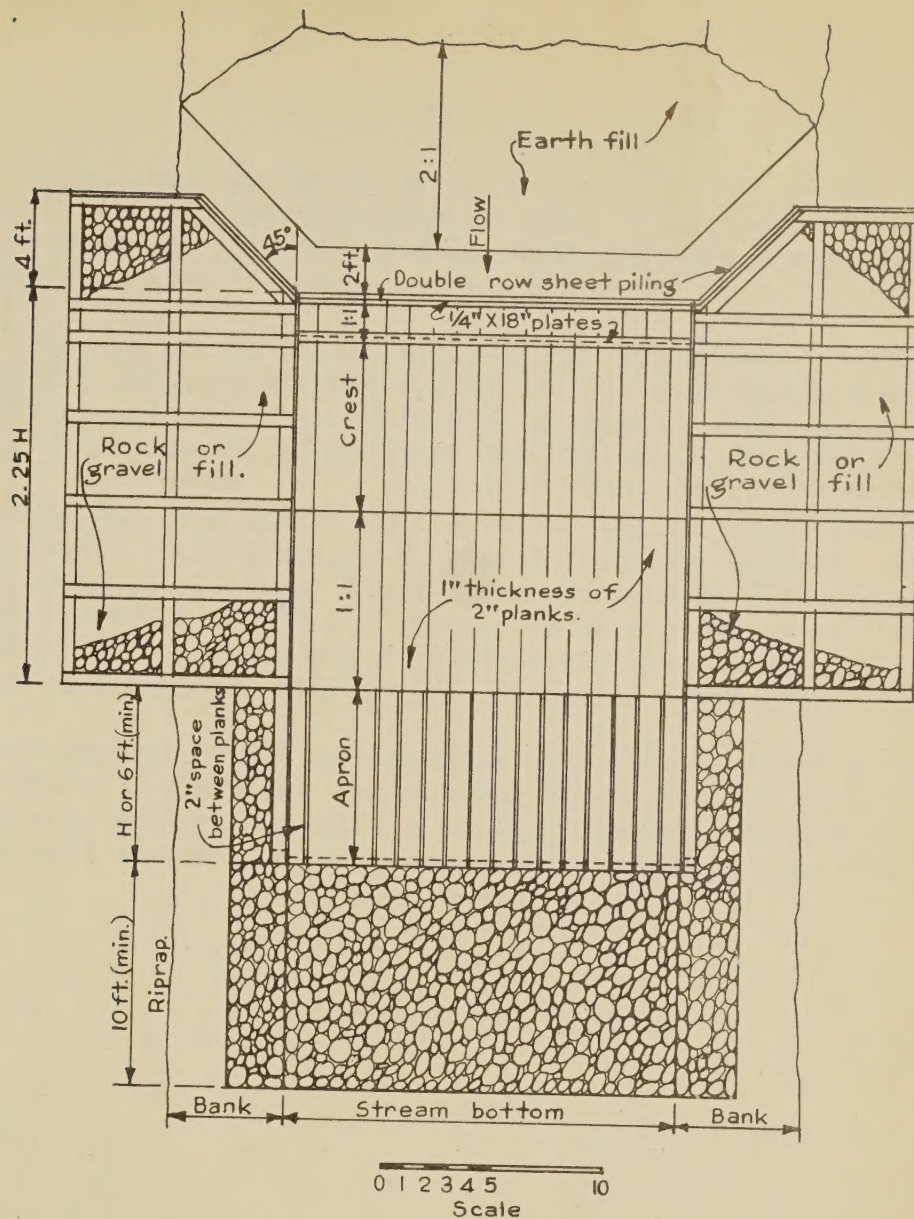| Depth above weir Feet	1	2	3	4	5	10	20	25	30	40	50	75	100	150	200
1.0	2.6	5.3	7.9	10.6	13.2	26.	53.	66.	79.	106.	132.	199.	265.	397.	530.
1.5	4.9	9.7	14.6	19.5	24.3	49.	97.	122.	146.	195.	243.	365.	487.	730.	974.
2.0	7.5	15.	22.5	30.	37.5	75.	150.	187.	225.	300.	375.	562.	749.	1124.	1498.
2.5	10.5	21.	31.5	42.	52.5	105.	210.	262.	315.	420.	525.	788.	1050.	1575.	2100.
3.0	13.8	27.6	41.4	55.2	69.	138.	276.	345.	414.	552.	690.	1035.	1380.	2070.	2760.
3.5	17.4	34.7	52.0	69.4	86.7	174.	347.	434.	520.	694.	867.	1301.	1740.	2600.	3470.
4.0	21.2	42.4	63.6	84.8	106.	212.	424.	530.	636.	848.	1060.	1590.	2120.	3180.	4240.
5.0	29.6	59.2	88.8	118.	148.	296.	592.	740.	888.	1184.	1480.	2220.	2960.	4440.	5920.
6.0	38.9	77.8	116.7	156.	194.	389.	778.	972.	1167.	1556.	1945.	2920.	3890.	5830.	7780.

/1   Computed from Formula: $Q = 2.65 \ LH^{3/2}$

Q = discharge in cubic feet per second
L = length of weir notch in feet
H = height of water above crest of weir

Earth fill

2:1

Flow

4 ft.

45°

2 ft.

Double row sheet piling

1/4" X 18" plates

Crest

Rock
(gravel)

or
fill.

2.25 H

1:1

Rock
gravel

or
fill

1" thickness of
2" planks.

Apron

H or 6 ft.(min.)

2" space
(between planks)

10 ft. (min.)

Riprap.

Bank

Stream bottom

Bank

0 1 2 3 4 5   10
Scale

Maximum H = 8 feet

Fig.12 - Plan of timber crib overflow dam.

Abutment

S

1.25 H

H

2 ft.

2" plank

3 ft.(min.)

H

6"X6"

3 ft.(min.)

Stream bed   3:1

Earth
fill

H or 6 ft. (min.)

10 ft. (min.)

12"(min.)

H (min.)

Rock or gravel fill

4 ft.

Sheet piling

0 1 2 3 4 5   10
Scale

1" space between plank
sheet piling

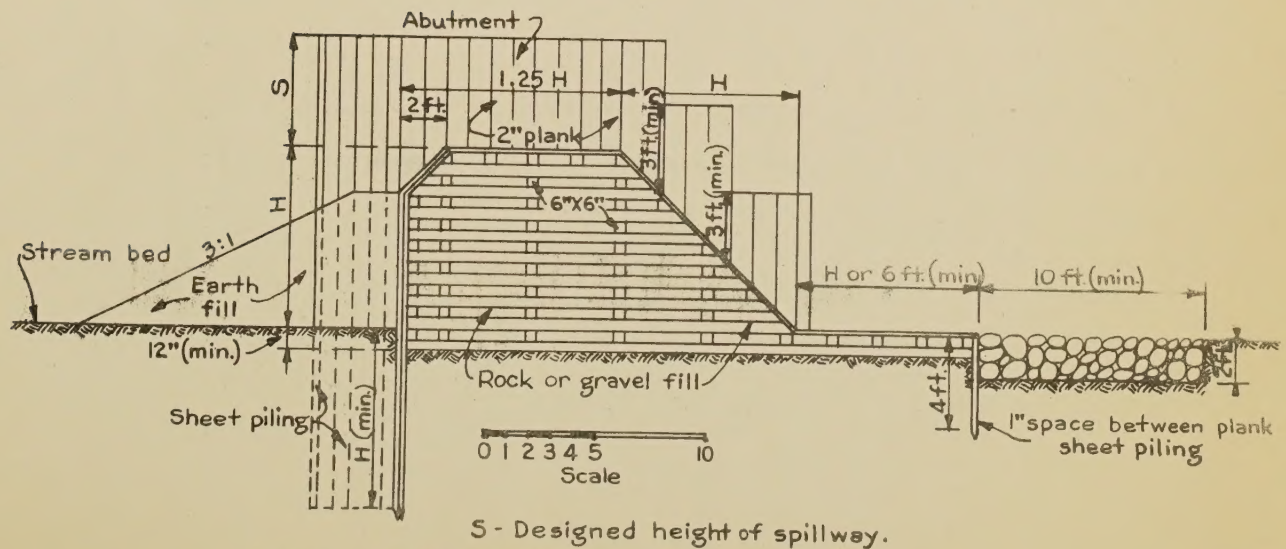S - Designed height of spillway.

Fig. 13 - Section of timber crib overflow dam.

The banks along the apron should be protected by riprap. The location and amount of riprap depends on local conditions. In all cases riprap should be laid to a 2-foot depth and a minimum length of 10 feet downstream from the apron. (See Figure 13).

The crib and piling should be lined up with a transit or chalk line so that the finished structure will have no open spaces between the sheet piling and the crib. This also produces a much neater job. The cribbing should be bolted together with 3/4 inch round bolts.

The upstream deck should be sloped and the abutments should be placed at an angle of 45 degrees in order to increase entrance velocities for all heights of dams. The decking consists of 2 inch plain planks. The stringers are 6" x 6" placed 4' on centers or closer if necessary to stiffen certain parts of the structure. There will be some waste of material but this should not exceed 5 per cent.

The foundation should be excavated to a minimum depth of 12 inches. If unstable soils are encountered the excavation should be continued to a greater depth until a better foundation is secured. The engineer must exercise careful judgment in preparing the foundation.